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Abstract Submission

TOPIC: CARBON MANAGEMENT

COMPARISON OF CO_2 FROM COAL CAPTUREPROCESSES AND VALORISATION TECHNOLOGIES TO ENHANCE ENERGY SUPPLY

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Abstract:

Coal is the most plentiful and evenly distributed fossil fuel worldwide. Based on current production, it is estimated that the reserves will last approximately 130 years. Its use worldwide has been increasing, mainly due to consumption by emerging countries. CO_2 emissions generated by combustion and the repercussions of such on climate change support the view that it could no longer be used. CO_2 capture may be the solution to continue using it, which would cater for the growing energy demand worldwide.

The aim of this study is to compare different processes concerning CO_2 capture that may be economically viable, ultimately showing that coal, a fossil energy source widely distributed around the world, can, as a result of using different CO_2 capture processes, be used as a clean source of electricity. Hence, in places where geological hurdles may render the costs of CO_2 storage considerably higher, since it might have to travel far, coal may be used for other purposes, thus valorizing CO_2 within the industrial sector.

This research is focused on the technical and economic comparison of the most relevant CO_2 capture projects designed in Spain using different existing technologies. The oxyfuel project in Ciuden (Leon, Spain), the IGCC Elcogas, precombustion CO2-capture project (Puertollano, Spain) and the postcombustion project in Carboneras (Almeria, Spain) will be analyzed in order to assess the options available to valorizecaptured CO_2.

Valorizing captured CO_2 may be an adequate solution in areas where, although CO_2 capture is still possible, storage is not equally so, thus generating a further benefit. The possible uses of CO_2 will be assessed in vegetable growing greenhouses, harnessing CO_2 in vegetable life cycles. This will also be used in growing algae for subsequent biodiesel production.

Both CO_2capture and valorizing will eventually lead to the clean use of coal, which will thus enhance the level of self-supply, aiding the development of electric vehicles, which require large amounts of electricity, as well as improve the level of energy autonomy in countries around the world. Another type of fuel, biodiesel, will also be obtained, without this affecting international food prices.

Keywords:CO_2 capture, clean coal, valorizing technologies, supply security

Objective of the Thesis

This extended abstract outlines the main points of the future thesis, the aim of which is to demonstrate how the sustainable use of coal, the most widely distributed fuel, can help the countries which produce it to improve their security of supply, to balance their imports, and to valorize theCO_2captured in such a way that theCO_2 can be used to feed algae for the production of biodiesel. As a result, the use of coal to generate electricity in a clean way will contribute to the development of electric cars and those fed on biodiesel, making cities places that are free from contamination and having a positive impact on countries' economies.

1 Introduction

1.1 Climate Change.

To understand why CO_2 emissions are affecting climate change and to find technical, economic and political compromise solutions which at the very least reduce the problem, we must take into account how the carbon cycle has altered and how this imbalance is linked to the greenhouse effect.
Some greenhouse gases occur naturally, whilst others are of an anthropogenic origin. As regards the process of elimination, all greenhouse gases(H_20, O_3, CH_4, N_20), are mostly eliminated by means of chemical or photochemical reactions within the atmosphere. On the contrary, CO_2enters in greater quantities into what is known as the carbon cycle, which has become unbalanced in recent years. Therefore the problem with$CO_2$is not its harmful nature, as it is a gas necessary for life, but stems from its high concentration in the atmosphere which causes an imbalance in the natural cycle.

The most significant changes studied in the concentration of CO_2, through the ice nuclei in Rostock, are mainly related to glacial cycles. Although glacial cycles are associated more directly to changes in the Earth's orbit, these changes also affect the carbon cycle, which in turn affects the glacial cycle.

In the last 1000 years, we have been able to zoom in on the correlation between CO_2 and temperature, focusing specifically on the last 40 years, when it can be seen that the historical trend has been broken and a rise in temperature has occurred.

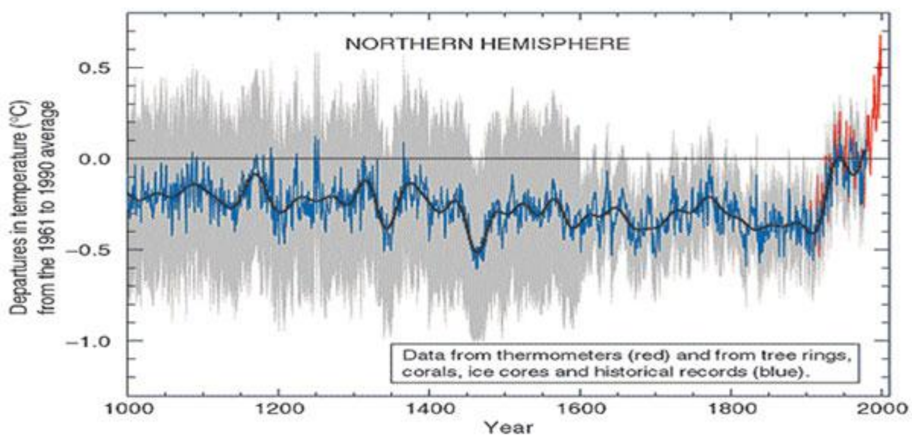

Figure 1. correlation between CO_2 and global temperature.

In the last few months many projects have appeared which dissociate CO_2 from being solely to blame for climate change, as we are probably faced with a combination of many non-anthropogenic factors which are causing the rise in temperature.As it is impossible for us to have an influence on the laws that govern the Earth's behavior, if our orbit is closer or further from the Sun, if the magnetic pole shifts more rapidly or slowly, etc., all we can do is study it. There is only one job for us to do, reduce greenhouse gas emissions, including CO_2. As it is our duty is not to wait for the future and try to guess what caused this effect or that, but to be ahead of the game and try to reduce emissions as much as possible, striving to combine ecological development in a sustainable and viable way, with economic and social development.

1.2 Security of supply.

It is important to highlight this concept, which must be accepted by society as one of the problems to resolve in the 21st century, through both economic policies and technological development.

The excessive dependency on energy which exists in many countries, mainly EU member states, causes significant imbalances in their balances of payments, which result in their external debt growing on a daily basis.

Delving deeper into the issue of security of supply, we must bear in mind the turbulent times being experienced by national energy markets as a result of recent geopolitical events. In relation to nuclear energy, in addition to the accident at the Fukushima plant, there has also been the decision by Italy and Germany to do away with nuclear energy. Not to mention the recent conflicts in Libya in relation to petrol, cuts in gas supply to Europe from Russia, and the ongoing disputes in the East regarding gas and petrol.

Abandoning coal mining, reducing its presence, and therefore depending on geopolitically unsettled countries for energy, doesn't only endanger the supply of fuels (gas and petrol) in situations of crisis, but also leaves governments and companies of the dependent countries without power at the time when the country's energy supply is being negotiated, leaving it vulnerable and as a result impoverished.

The capture ofCO_2, both its storage and its valorization, is clearly an economically viable solution for coal producing countries, which experience pressure as a result of pollution and climate change to abandon this fuel. Therefore, its clean use, provides security of supply, limits the prices of electrical production, supports the intermittence of renewable energies, is a high quality source, and will clearly facilitate the possibility to develop the electric car, as it needs an electric supply, independent of the climate conditions, generally at night, therefore a balanced mix of electricity generation will be needed, in which coal with the capture of CO_2 will have to play a part.

2 Capture, transport and storage of CO2.Projects in Spain.

In November 2007 the European Strategic Energy Technology Plan [1]was introduced which outlines the efforts that the European Union must make to produce competitive, safe and sustainable energy and the fact that the challenges related to climate change, security of energy supply and competitiveness require a coordinated response.
To achieve this, in recent years strategic research projects have been financed at aninternational level. At European level, there is the platform"Zero Emissions Power" (ZEP)[2] , comprising companies, scientists, academics and non-governmental organizations with the objective of cooperating on issues related to the capture and storage of CO_2 (CCS).
In Spain there is the Spanish CO_2 Technology Platform[3] . The general scope of this platform is to tackle technological development in Spain which contributes to reducing the impact of greenhouse gas emissions in the country. Its success mainly stems from the huge participation of companies and public organizations, and awareness-raising to achieve social acceptance of the Capture and Storage of CO2 (CSS).

Of the CCS R+D projects in Spain, we can report that a wide range of technologies are being developed ranging from Oxifuel in the plant at Compostilla (ENDESA) + CIUDENin the Bierzo region (León, Spain) , Carbonatación Capturación (Carbonation Capturation), a project by the public coal mining company HUNOSA+ ENDESA +Foster Wheeler, (Asturias, Spain), the IGCC of ELCOGAS (Puertollano, Spain), and the station of ENDESA inCarboneras, (Almería, Spain) in which post-combustion technology is being developed.

2.1 Capture in Post-combustion.

Capture in post-combustion refers to the separation of CO_2 from the flue gas produced from the combustion process. In the case of the pulverized coal plants which exist in power stations in many countries, including Spain, they can be subcritical, supercritical or ultra-supercritical, depending on the pressure at which they operate.
Nowadays, this is the most commonly used method for the separation of CO_2 from diluted currents at low concentrations.

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[1] Plan Estratégico Europeo de Tecnología Energética (EETE). Documento completo http://europa.eu/legislation_summaries/energy/european_energy_policy/l27079_es.htm
[2] ZEP http://www.zeroemissionsplatform.eu/
[3] Plataforma Española del CO2. http://www.pteco2.es/

In this system, theCO_2has been separated from the flue gases produced during combustion (mainly N2) with air from a fuel (coal, natural gas, etc.). For its subsequent capture, the most viable processes include the Calcination/Carbonation cycle and chemical absorption with amines.

a) Chemical absorption.

In this process,CO_2 reacts with an absorption liquid. For this, chemical compounds are used (amines and new absorbents being researched) with a high affinity of acid compounds (CO_2) and are used as formulated solvents, in a special mixture adapted to the task of separation. Some of them also contain activators to boost the transfer of mass in absorption. In table 1 some solvents that are commonly used to carry out this task are shown.

Type of solvent	Example
Primary amines	Monoethanolamine (MEA) Diglycolamine (DGA)
Secondary amines	Diethanolamine (DEA) Diisopropanolamine (DIPA)
Tertiary amines	Methyldiethanolamine (MDEA) Triethanolamine (TEA)
Alkaline salt solutions	Potassium carbonate

Table 1of solvents used in the process

Currently the following solvent processes are commercially available for the treatment of CO_2.

1. *Kerr-McGee/ABB Lummus Crest Process (Barchas and Davis, 1992).*
2. *Fluor Daniel ECONAMINE Process (Sander and Mariz, 1992, Chapel et al., 1999).*
3. *Kansai Electric Power Co., Mitsubishi Heavy Industries, Ltd. Process (Mimura et al.,2000).*

The detailed process can be seen in figure 2. The system is broken down into two main stages: absorption and regeneration (increase in temperature and energy consumption).

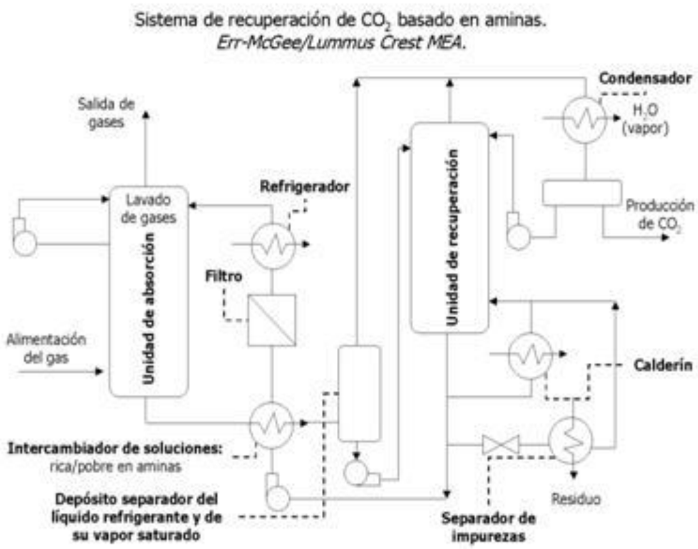

Figure 1 Detailed chemical absorption process

The stages in the process are described simply in the diagram in figure 3. Below is a detailed explanation of the stages in the system.

1. The gas containing $CO_2$is put into contact with a liquid absorbent capable of capturing CO_2.
2. The absorbent loaded with $CO_2$is transported to another tower where it is regenerated using changes in temperature or pressure and releases theCO_2.
3. The regenerated absorbent is sent again to the CO_2 capture process.
4. To counteract losses of activity in the absorbent, new absorbent is constantly added.

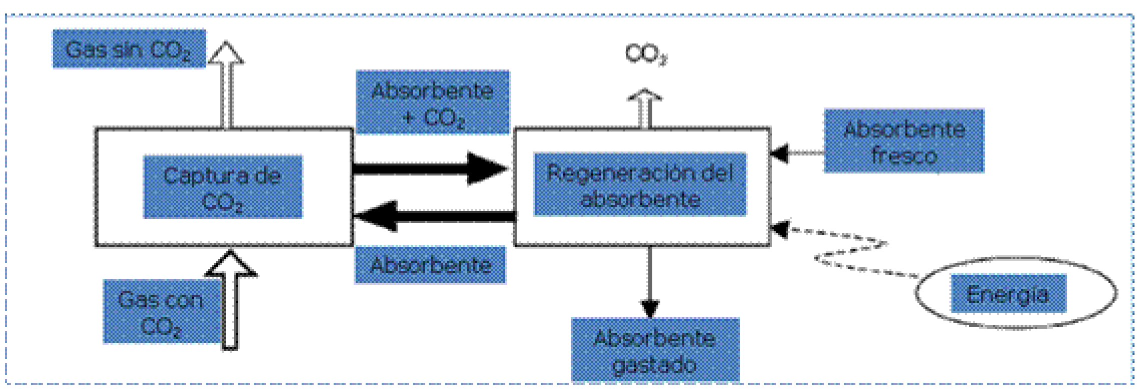

Figure 2. Stages in the chemical absorption process

When using this system its basic operating characteristicsmust not be ignored, which can determine its viability. These include:

1. The chemical reaction of the process takes place at a high temperature.
2. The system consists of one reactor in the form of an absorber and another which acts as a regenerator of the amine.
3. The regeneration process requires considerable energy consumption.
4. The system requires prior treatment of the combustion gases, due to the fact that the amines are highly penetrable by nitrogen and sulphur oxides(NOx and SOx)

b) Calcination/Carbonation cycle
This combination of processes is based on chemical absorption, using limestone as an absorbent. To define them separately,

carbonation is an exothermic reaction in which the reactive agents CO_2 and CaO react to produce $CaCO_3$. The energy which is released by this reaction is 430 kcal/kg CaCO3. On the contrary, calcination is the reverse process, as it produces the desorption of $CO_2$and CaO through the decomposition of limestone in the presence of heat.

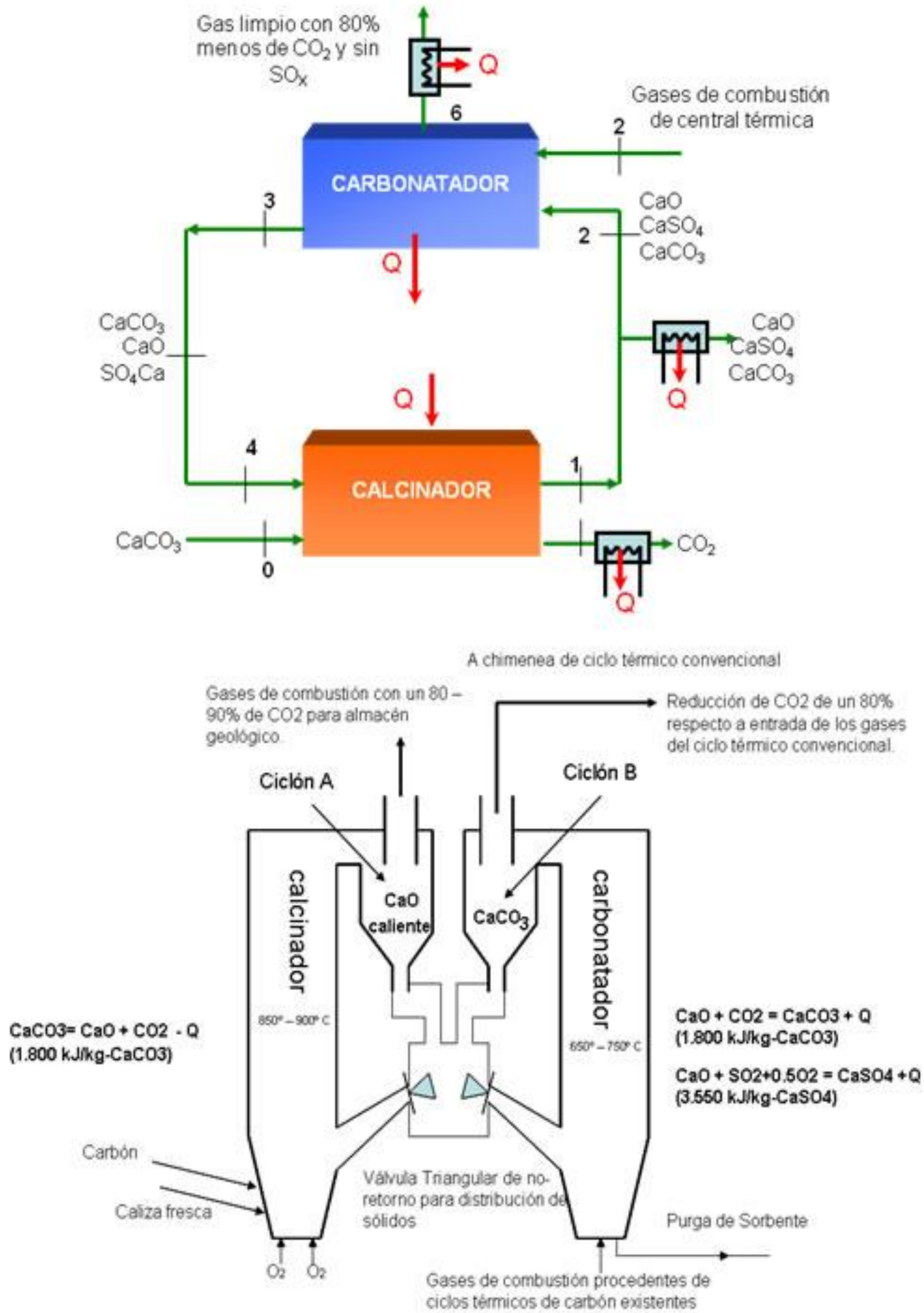

Figure 3.Diagrams showing how calcination/carbonation technology works

The stages in this process are:

1. The current of gases for treatment is taken before it enters into the desulphurator (D.G.C.).
2. The proposed process will work on two interconnected circulating fluid layers, operating at a temperature of 650 ºC for the

one acting as a carbonator, and at 875 ºC for the one working as a calcinator.
3. The calcinator will work in oxy-combustion, with the objective of generating a high current of CO_2 in the output gases.
4. The recuperation of heat in the new cycle proposed is achieved by means of a supercritical water-vapor cycle.

c) Physical adsorption:

Basically this involves using materials capable of adsorbing CO_2 generally at high temperatures, to then recover it through temperature or pressure changing processes (TSA and PSA processes respectively). The adsorbents mainly include active carbons and zeolites.

The most significant post-combustion and CO_2 valorization project in Spain, is being carried out at the station in Carboneras (Almería, Spain).

2.2 Capture inPre-combustion

Another way of capturing$CO_2$is by increasing its partial concentration and pressure before carrying out combustion. This requires the separation of the CO_2 once the coal is gasified and converted into a synthesis gas rich in carbohydrogen. One of the European Union's flagship programs resulting from the EU's Sixth Framework Program, is ELCOGAS, situated in the town of Puertollano (Ciudad Real, Spain). This is a 335 MW_eIGCC which uses as a fuel a mixture of 50% autochthonous coal from the open-pit mine of ENCASUR (Emma Mine), owned by the electricity company ENDESA, and petroleum coke from the refinery situated in the same town and owned by the company REPSOL. In fact, its proximity to the emblematic refinery makes ELCOGAS one of the ideal stations for the capture and subsequent valorization of CO2, with the latter being used to feed a future algae plantation for the production of biodiesel in the installations of the refinery owned by REPSOL.
ELCOGAShas developed an experimental 14 Mw_eplant with capture ofCO_2 and procurement of H2, which has been in operation since spring 2010.
The pilot plant is fed with approximately 2% synthesis gas produced in the GICC plant, i.e. 3.600 Nm^3/h (dry base) which is the equivalent to approximately 14 MWt.

Operational methods

Synthesis gas be fed to the desulphurized pilot plant (called sweet gas), in other words, downstream from the desulphurization unit of the GICC station or upstream from this desulphurization system (called acid gas), as this is designed to be able to operate with both types of gases. Sweet gas, also known as clean gas, presents the characteristics shown in the table below.

Pressure: 22.6 bar	
Temperature: 137.6 ºC	
Flow: 3.600 Nm^3/h	
Power: 14 MWt	
Composition (% volume)	
CO	60.4
H_2	22.0
CO_2	2.6
N_2	14.0
Ar	1.0

Table 2 Characteristics of clean synthesis gas which is fed into the pilot plant

The composition of desulphurized gas (acid) varies slightly compared to the above as it also contains H_2S and COS.

Below is a diagram showing the blocks which make up the process in the pilot plant, as well as its integration with the GICC plant, in both feed gas (sweet or clean gas, and acid or unrefined gas) and in the destination of the currents (all the currents generated are returned to the process by means of an existing compressor).

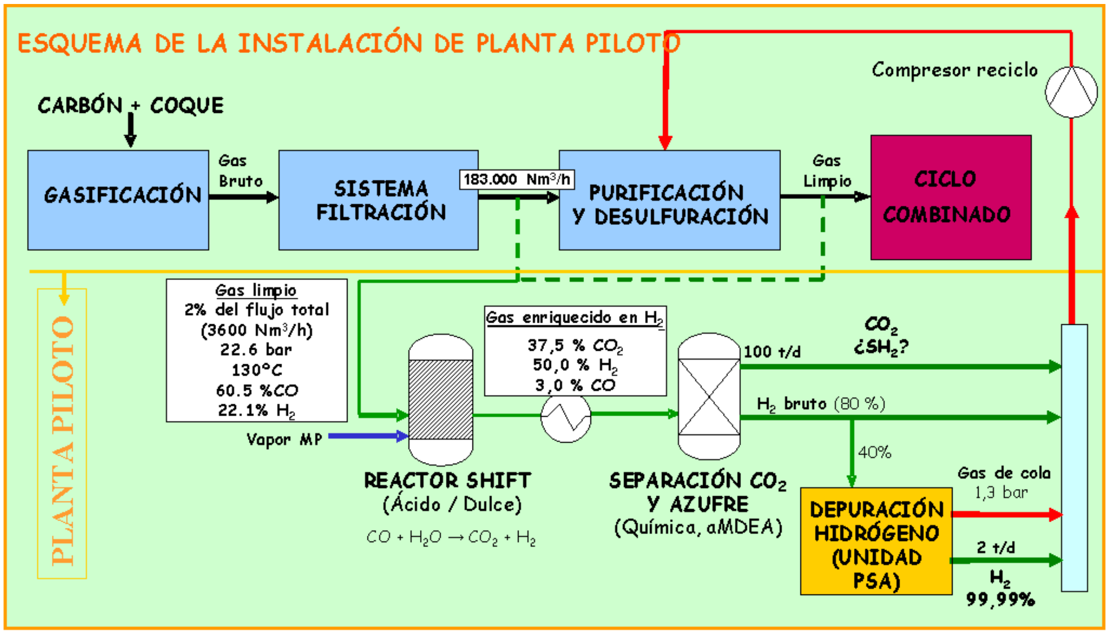

Figure 4. Diagram Pilot Plant Capture of$CO_2$and production of H2 of ELCOGAS

The pilot plant basically consists of three very different stages as shown in the following diagram (including its integration with the GICC plant) which are described below.

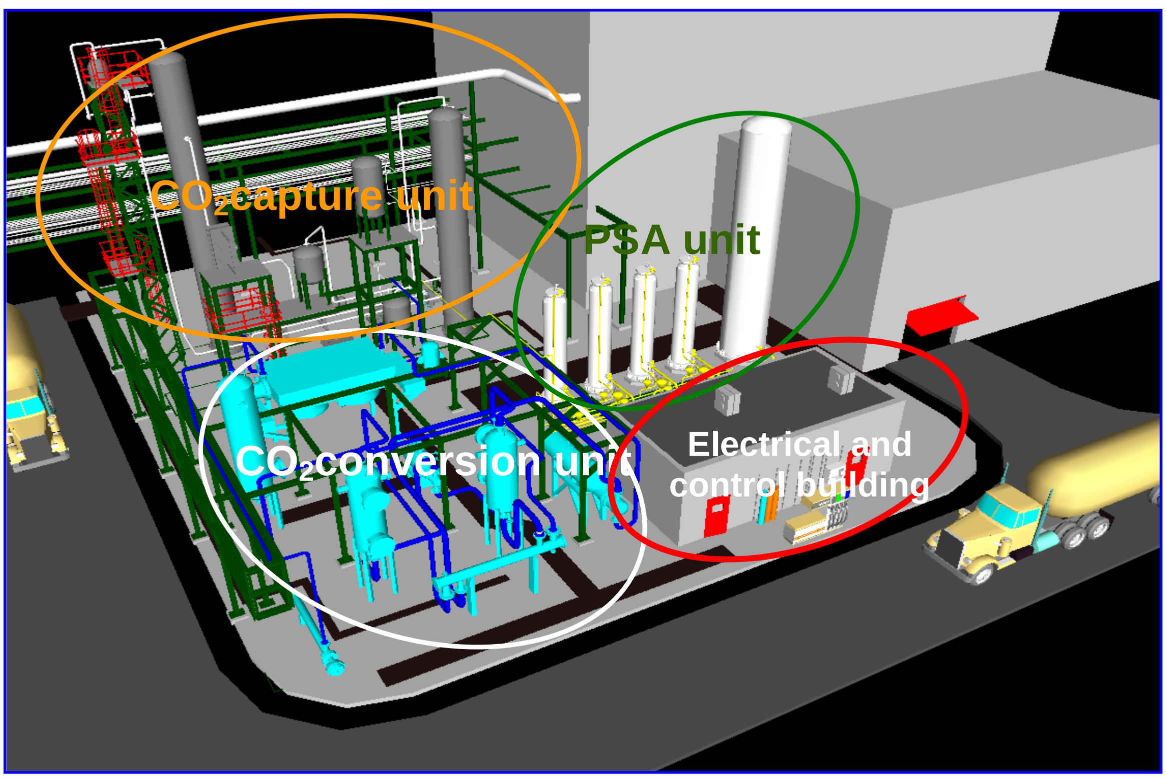

Figure 5. 3D recreation of the pilot plant identifying its units

Stage nº 1: Conversion with water vapor (CO_2conversion unit)

The objective of this first stage is to modify the composition of the synthesis gas, mainly made up of CO and H_2, to increase its CO_2 and H_2content.

Essentially, the process involves the synthesis gas from the GICC station desulphurizing in the desulphurization reactor (consisting of a filled layer of Zn oxide based absorbent), medium pressure saturated water vapor being injected into it using a static mixer to achieve a good homogenization of the current and then it is heated in a preheater at 310 ºC. After that, it passes through two catalytic reactors for conversion (*shift*) –supplied by Johnson-Matthey- in which the conversion of CO to CO_2 and H_2takes place according to the following chemical reaction:

$$CO + H_2O = CO_2 + H_2$$

The gas-vapor mixture is then fed to the first reactor*shift*,which is at a high temperature and the conversion reaction take place until it reaches a temperature of480ºC. After an intermediary cooling stage, the temperature of the gas falls to 350ºC and it enters into the second reactor*shift*where it will react up to approximately 390ºC,allowing the reaction to reach a suitably advanced stage of conversion. After conversion, the converted gas is cooled to 160 ºC in two preheaters, producing water vapor at a very low pressure.Then, it is cooled to 80ºC in an aero-refrigeratoruntil it has reached a temperature of 45ºC.

After this step, the gas obtained is richer in H_2 and has a higher CO_2content than the original, with the following composition (% volume):

Pressure 5.9 bar	
Temperature 45 ºC	
Composition (% volume)	
H_2	50.0
CO_2	39.5
CO	3.0
N_2 + Ar	9.5

Table 3. Composition of gas enriched in H_2 (after stage nº 1 in the pilot plant)

Stage nº 2: Separation of CO_2 and H_2 (CO_2capture unit)

The purpose of this second stageis to separate the CO_2 from the current of gas and obtain a gas which is richer in H_2. To achieve this a non-selective chemical absorption process is used.

Then, the gas enriched in H_2produced during the conversion stage (5.700 Nm^3/h, as after it is passed through the "Shift Converter" the flow of gas for treatment increases) is fed into the bottom to a CO_2 absorption column, whilst the absorbent is added to the top of the it. The gas is washed against the current with an amine solution (aMDEA, activated Methyl-Di-Ethanol-Amine) which enables capture of the CO_2. After the CO_2 is captured, a current concentrated in $H_2$is obtained (called crude hydrogen)which comes out the top of the absorption column and has the following composition:

Pressure 15.6 bar	
Temperature 40 ºC	
Composition (% volume)	
H_2	77.4
CO_2	6.5
CO	2.9
N_2+ Ar	13.2

Table 4. Composition of crude H_2after the second stage in the pilot plant

This crude hydrogen can be sent to the gas turbine in the GICC station or be passed on to the next stage of the pilot plant.

The amine loaded with $CO_2$is fed to a desorption column where the gas is desorbed by increasing the temperature and decreasing the pressure. In this way, the amine is regenerated and returns to the absorption stage in a closed circuit after being cooled. In the desorption column a current highly concentrated in $CO_2$of 100 t/day is obtained which can be fed to the gas turbine or can be released into the atmosphere. The percentage of CO_2capture is estimated to exceed 90 %.

Stage nº 3: Purification of H_2 (PSA unit)

This third stage allows you to obtain pure H_2 from the current of crude hydrogen (77.4% pure) produced in the previous stage.

This way, part of the crude H_2produced in the previous step (40 %) passes to this stage for purification and the rest of the crude H_2produced will be fed into the gas turbine.

The purification process consists of separating the products which accompany hydrogen in this current (CO_2, CO, N_2, Ar) using a PSA unit (*Pressure Swing Absorption*) in which these substances are trapped in an absorber system of multiple layers of filtering material, whilst the H_2passes freely through them. These layers operate in alternating cycles of adsorption and regeneration once their capturing power is exhausted to provide a continuous and constant flow of hydrogen current. The purification unit consists of four stages: adsorption, depressurization, final regeneration with purge at low pressure and re-compression.

A PSA, in its most simple form, requires two absorbent layers, in such a way that whilst one is in the stage of adsorption the other performs the three stages of regeneration.With a minimum of four layers the losses of H_2originating in the decompression stage are minimized, by using the desorbed gas to increase the pressure of other layers in the re-compression stage.

The estimated production capacity of pure $H_2$is 2 t/day and its expected final purity is99.99 % volume (purity for commercial uses). A total recovery of H_2higher than 95 % is expected.

The producer gas generated in the regeneration phases of the PSA called tail gas, can also be sent to the gas turbine or can be used as a source of heat in other processes.

Figure6. Detail of the H_2purification unit (PSA unit)

The table below summarizes the main characteristics of the input and output current of the pilot plant:

Characteristics of clean synthesis gas (input into pilot plant)				
Flow	3.600 Nm^3/h (dry base)			
CO (% volume)	60.5			
H_2 (% volume)	22.1			
Characteristics of the CO_2 and H_2 output currents (output from the pilot plant)				
Productionof CO_2	100 t/day	**Percentage of capture of CO_2**	> 90%	
Production ofpure H_2	2 t/day	**Puritypure H_2**	99.99%	
Production ofcrude H_2	5 t/day	**Puritycrude H_2**	77.4 %	

Table 5. Summary of the technical characteristics of the pilot plant

Of this plant's achievements, it is worth highlighting that the public works began in 2008 and it was launched in May 2010, achieving its first ton of captured CO_2 in October 2010.

We can consider that IGCC technology can clearly contribute to the capture of CO_2 with various advantages in our case. In addition to theobvious use of valorization of CO_2 for the production of biodiesel from algae, the mass production of H2can also play a significant role in the manufacture of fuel batteries.

2.3 Capture in Oxyfuel.

This process is performed during combustion and has a long journey in applied technology. It basically involves the use of oxygen instead of air for combustion, which is why the flue gasesare mainly composed of H_2O andCO_2, which can be easily separated from water vapor through condensation.

A basic diagram of how it works is shown below. This technology is used in new generation stations with extremely critical water-vapor cycles, in addition to Gas Turbines with or without recovery boilers.

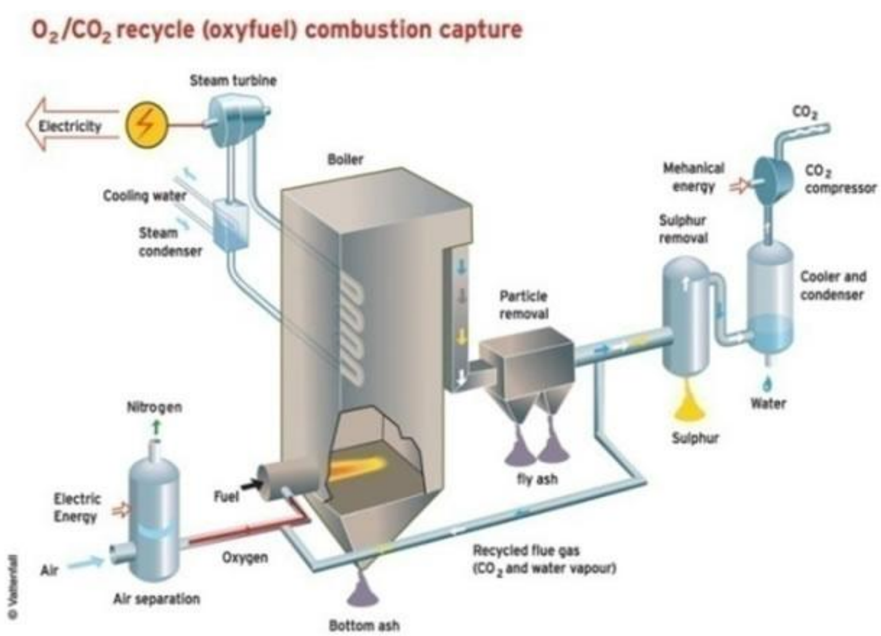

Figure 7. Diagram of Oxifuel.

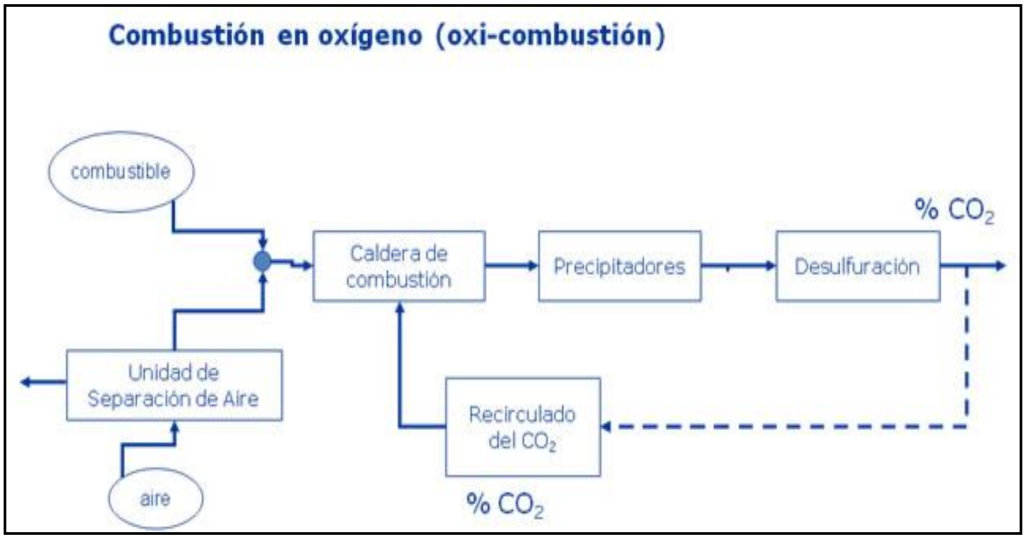

Figure 8. Design and diagram of operation of oxy-combustion

As it is a technology which is currently being developed, there are many research projects on the subject which search for better applications and efficiencies of costs. The table below shows the most important aspects to develop in the different aspects of this technology.

Table 6. Aspects to develop in calcification/carbonation

Aspect of the process	**Critical areas for development**
ASU (Air separation unit)	1. Cryogenic distillation. Auxiliary consumption. 2. Ceramic membranes which increase efficiency.
O2 combustion	1. Combustion, ignition, flame stability, temperatures and flame profiles. 2. Home volume. Thermal absorption per unit of surface. 3. Degree ofCO_2 recirculation**.**
Philosophy of operations	1. Operational flexibility. 2. Integration of the ASU. 3. Disposaljets of pure O2, recirculated $CO_2$and transport of carbon.
Emissions	1. The kinetics of NOx in coal flames is not applicable. 2. Kinetics of SO_2. 3. Ash composition.
Materials	1. Operational properties in the long-term and at high temperatures. 2. Tests of ultra-supercritical advanced materials. 3. Potential of corrosion for coals with high content of ash, S, Cl.

Within the UE, it is worth highlighting the demonstration plant in Vattenfall (Germany) and the demonstration plant inEl Bierzo (León, Spain) , both of which have received EU financing.

3 Valorization ofCO_2. Projects.

Security of supply, and the possibility of developing a more ecological form of transport, how the electric car, need a continuous source of continuous energy, and no intermittented, in other words, it needs conventional energy that not dependent on climatic variations and therefore complement and support thedevelopment renewable energy, whose presence will increase exponentially in coming years.
The use of clean coal, capturing the CO_2 will be a reality and a necessity in the coming years.

Storing CO_2 is a possible solution, which also may allow the recovery of most gas natural.Not only one solution must find ways to captured CO_2 burial, but the use of CO_2on an industrial scale should be investigated by the scientific community, in order tot emissions from the commercial scale of the next projects to capture CO_2can be absorbed so competitive.

In addition to the current exploitation of CO_2in the feed, water treatment and industrial processes.

In Spain there is a three important R&D projects with valorization of CO_2

3.1. Greenhouse projects.

The power station “Litoral” in Carboneras (Carboneras, Almería, Spain), owned electricity company ENDESA is very close to the greatest extent European greenhouses for tomato production. We're talking about an area of 26,500 hectares (equivalent to 65,500 acres), where the needs of CO_2 are potentially enormous. Carbon dioxide injected into the greenhouses increases crop yields.

3.2.Biodiesel algae project.

In Spain, several projects are being developed for the generation of microalgae that will be used to capture CO_2 to create biodiesel.

One of the most important projects is also being performed at the plant of Carboneras (Almería, Spain), where carbon dioxide is injected in the greenhouses, so this plant is the closest to develop the valorization of CO_2. Carboneras is one of the projects promoted by the CENIT CO_2 research program [4] promoted by the Ministry [5] Science and Innovation in Spain.

Another important project in the development of microalgae for biodiesel generation, is led by the Spanish company REPSOL, where one of its refineries are located in the same location as the IGCC power plant ELCOGAS, as seen in paragraph 2 . The CO_2 captured in ELCOGAS will serve as “food” for microalgae.

The advantages of plantations of microalgae in general lie in one of the most efficient photosynthetic organisms use solar energy, 8% versus 2% of other crops. Productivity estimates are as high as 60-80 tons of dry weight per hectare (2.47 acres) per year, while for the rest of conventional crops, there are around 10 to 30 tons.

The production of biodiesel in those Spanish projects in the demonstration phase, you will get 150 to 300 kg of biodiesel per acre per day.

Regarding production costs and by Y. Chisti [6] estimated that the production of microalgae biomass costs $ 2.95 if it comes from fotobirreactores technology, cheaper than in the carousel system whose acquisition price would be $3,50. These estimates assume that CO2 would be available at no cost, something is not right, but it does cheapen a lot with the large scale production of the CSS and the proximity of algae production systems to the generators of CO2. For the annual production of 10,000 tons of biomass, the production cost per kilogram was reduced to $ 0.47 in the case of photobioreactors and $ 0.60 for open systems carousel. Biomass has about 30% oil by weight the cost of production would be between 1.40 and $ 1.81. A reasonable price would be $ 0.48 so that the strategic objective would be to reduce their production costs.

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[4] Programa Cenit CO_2 http://www.cenitco2.es/
[5] Ministerio de Ciencia e Innovación.http://www.micinn.es/
[6] Y. Chisti “Biodiesel from microalgae” Biotechnology Advances 25, 294-306,2007

4 Economic repercussions on a coal producing country. Case study on Spain.

Currently 9 million tons (hard coal) are produced in Spain which feed a total of 8 electrical power stations which consume coal in a mix generally consisting of 60% autochthonous coal and 40% domestic coal. Electricity generation in the electrical power stations which consume coal in Spain amounts to around 20% of the country's electricity. Doing without this technology due to CO_2 emissions, would be an economic catastrophe in a coal producing country. We are referring to the fact that coal-based electrical power stations would therefore have to be replaced by other thermal stations using imported fuel.

Nowadays there is much talk about the golden age of natural gas. For a country like Spain it would involve a total dependency on this fuel if coal mining were to cease. We mustn't forget that the success of combined cycles fed with gas, lies in their high efficiency which exceeds 65% of the return and which therefore produces a lower emission of CO_2 into the atmosphere, but this technology also comes faces the challenge of capturing CO_2, if it is to be considered a clean technology.

Therefore, doing without coal, and transferring to a dependency on natural gas for a country like Spain, where the only other fossil fuel is gas, would result in a strong imbalance in its external debt. Currently, 50% of imports in Spain come from energy products. This would constitute an economic sentence which would financially cripple a country dependent on the outside for over 87% of its energy, which considerably exceeds the European average.

In economic terms, the investments necessary for thermal generation are in excess of 15,000 euros, which would be in nuclear or gas combined cycle plants. In addition, these combined cycles should develop CO_2 capture plants, increasing the investment by 5000 million euros.

The import of fuel for Spain which to substitute domestic coal would cost around 4000 million euros each year.

Saving and energy efficiencyare challenges to achieve, but it is also important to consider that the forecasts for the growth of demand in the next few years will substitute the thermal gap due to the saving.

Therefore, continuing with thermal coal plants in addition to capturing CO_2, involves an investment for Spain of only 5000 million euros, and an annual fuel saving of 4000 million euros.

5Advantages linked to the capture ofCO_2. Electric car. Clean cities.

The capture of $CO_2$for the combustion of coal is a challenge which must be supported by governments and the international community. Coal reserves in the world provide for 140 years of consumption, which is sufficient time for the development of renewable technologies, which will be capable of storing the energy that society will need in the future.

Its availability worldwide, means that it is the fuel which has caused the least conflict in the world. Almost all countries have coal reserves, of either brown coal or hard coal.

The development of the electric car, will clearly depend on the prices of electricity in the future and these in turn on technologies, which are used for the generation of electricity.

The generation of electricity with coal, has an average cost of 45€/MWh, compared to generation with CO_2 capture which is estimated at 65€/Mwh, including CSS technologies, and this is still cheaper than solar and wind energy.

Capturing $CO_2$from the combustion of coal will limit electricity prices, in addition to a continuous contribution to electricity demand for recharging batteries, including at night.

In this way cities with electrical vehicles will be places free from pollution, whilst in coal plants, CO_2 will be captured and subsequently used in the production of biodiesel (Repsol Project, Puertollano, Spain)and in greenhouses where it will accelerate the cycle of plants, with the contribution of CO_2. (Carboneras Project, Almería , Spain)

6. Conclusions.

For all these reasons, we conclude that the use of coal with CO_2 capture and the subsequent recovery of carbon dioxide, will allow the use of a fuel widely distributed globally, improving security of supply in many countries.

This will get reasonable prices of electricity and should balance energy imports.

It will also allow coverage to cover the growing energy demand, improve supply the electricity needed to meet that need the electric car and you get competitively priced biodiesel for other transports (aircraft, trucks).

Do not use large amounts of food crops used to produce the biomass, which caused very high price increases, being very unfair to developing countries.